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AD-A226 725

Understanding the Adoption of Ada: Results of an Industry Survey

Marthena Carlson
Gordon N. Smith

May 1990

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Special Report

SEI-90-SR-10

May 1990

**Understanding the Adoption of Ada:
Results of an Industry Survey**



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FI9-628-85-C-0003

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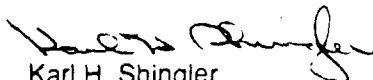
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Acknowledgements

We thank those firms and individuals who gave so freely of their time, ideas, and experiences to clarify and further develop our understanding of Ada, the defense industry, and technology adoption decisions. In particular, we wish to thank Richard Martin, William Hefley, and Jane Siegel for sponsoring this study and for their valuable advice and assistance. We also wish to thank John Foreman and David McKeehan for their assistance in the formulation stage of this research, Maya Sternberg for data assistance, our research assistants, and several reviewers within the SEI for their help during various stages of this study.

Understanding the Adoption of Ada: Results of an Industry Survey

Abstract: In 1983, the U.S. Department of Defense (DoD) established a policy requiring the use of a new programming language, Ada, for the development of all new Mission-Critical Computer Resource (MCCR) software that it purchases. Firms that supply the DoD with these systems have shown considerable variation in their decisions to incorporate this new technology into their products and production processes. This survey is part of a multi-stage research project that sought to understand the variability in firms' adoption and use of new information technologies. The present report is a follow-up and elaboration on a case study of the adoption of Ada which is described in CMU/SEI-89-TR-28, *Understanding the Adoption of Ada: A Field Study Report*.

Participants in the survey were 123 business and technical people from 69 business units that supply the DoD with MCCR software systems and services. The survey explored factors pertaining to respondents' technical and market environments in an attempt to describe depth of adoption and to describe the differences between the firms with active Ada contracts and those without active contracts. For firms that have adopted Ada the report describes aspects of the language and tools that are considered most useful in different application areas. At present, 85% of the units have proposed to use Ada as a primary implementation language, and 70% have been awarded a contract in which Ada is the primary implementation language. Within the context of this study, Ada contract awards have been in the following application areas: aircraft engines, attack radar, display processors, flight control, flight trainers, ground control vehicles, night vision, radar warning receivers, missiles, space command and control, and tactical command and control. Survey participants reported that Ada is being used in 50% of the new development contracts and is being proposed for use in 60% of the contracts in the proposal stage.

1. Study Background

1.1. Introduction

Like other new technologies, software engineering innovations have been subject to substantial delays in their adoption and use [Redwine 85, ACM SIGSOFT 84]. The potential importance of this class of information technologies, and the importance of understanding firms' technology adoption decisions in general are the motivating factors for the present study and its predecessor, a case study. Previously, Smith et al [Smith 89] conducted a case study of seven business units from DoD contractors that made decisions about the adoption and use of Ada. Their findings indicated that contractor decisions about adopting Ada were influenced by:

1. The technical merits of the language.
2. The software development expertise of the staff.
3. Their perceptions of customer demand for Ada systems.

The present study extended the scope of the case study to a larger set of factors associated with Ada adoption and to a more extensive list of business units and application areas. For an explanation of the history of Ada, a further characterization of MCCR software, and the stages of military software procurement, see Appendix A.

1.2. Survey Design and Methodology

Although Ada is a general-purpose, high-order programming language, in the U.S. it has been MCCR firms and industries in which this new information technology has been most aggressively evaluated, adopted, and used. The pool of potential respondents was drawn from firms supplying 13 different types of MCCR software and systems to the DoD. Application areas were chosen to assure variation across some key industry-level factors—such as business unit size, expertise in the application area, number of competitors, and primary customer—in order to explore the potential effects that these factors have on firms' Ada adoption decisions. We sought the perspectives of senior business and technical personnel within each business unit. The 13 application areas chosen were: aircraft engines, attack radar, display processors, flight control, flight trainers and simulators, ground control vehicles, ground surveillance radar, missiles, night vision, radar warning receivers, space command and control, tactical command and control, and torpedoes.

Firms operating in each application area were identified using multiple sources, including trade association directories, industry journals, the Corporate Technology Directory [CorpTech 83], and SEI technical staff recommendations. Also, survey respondents were asked to identify their competitors and those organizations were also contacted about survey participation.

Each firm was telephoned to identify contacts within the business unit(s) of interest. Individuals were contacted, given a brief introduction to the survey, and asked to participate by scheduling a time to conduct the interview. Respondents received a packet containing the appropriate questionnaire (business or technical and tailored to the application area) along with a cover letter reviewing the purpose, procedures, and confidentiality of the study. A copy of each questionnaire is in Appendix B. Of the 123 respondents, 82% were interviewed by telephone and 18% chose to return the completed questionnaire by mail.

1.2.1. Description of the Respondents

The questionnaire was completed by 55 business respondents and 68 technical respondents. There were 51 pairs of respondents, meaning that both a technical and a business person from the same company and application area completed the forms. Table 1-1 shows, by application area, the number of respondents and the minimum and maximum values for a selected set of business unit variables that characterize the firms. The variables selected were:

- Business unit revenues.
- The average number of contractors that compete in the market.
- The number of years the unit has been developing software in the application area.
- The number of software personnel in the business unit.
- The percentage of the market share that the business unit has in the application area.

Some of the individuals responding were not included in Table 1-1 because there were too few participants in that application area to guarantee anonymity of the data. All responses from all individuals are reported in other analyses and tables unless otherwise noted.

Looking at Table 1-1, we see the revenues of the business units range from \$5 million to \$7 billion, the number of software personnel ranges from a minimum of 2 to a maximum of 6500, and the market share ranges from 1% to 100%. Some firms began supplying software in their application areas from the beginning of software use, while others are relatively new participants in their fields. The column showing the number of contractors competing in an application area can be used to illustrate that some application areas are more competitive than others and also as an indication of the representativeness of this sample in the different application areas. The responses to 50 questions that were common to both questionnaires were examined to see if there were differences between business and technical respondents. The results were nearly identical and do not require separate reporting.

Table 1-1: Description of the Respondents

Application	Respondents		Business Unit Revenues in Millions of \$		# of Competitors		# Yrs Active in Software Development		# of Software Personnel		% Market Share	
	#Bus	#Tech	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Aircraft Engines	2	2	7000	7000	2	7	11	21	20	3500	40	50
Attack Radar	2	4	37	500	4	5	14	29	75	500	30	50
Display Processors	2	2	125	125	5	6	7	29	30	50	30	66
Flight Control	6	8	170	300	5	10	9	27	15	60	5	40
Flight Trainers	6	6	20	70	5	25	2	31	10	300	5	42
Ground Control Vehicles	2	2	15	15	5	15	2	21	40	50	60	100
Ground Surveillance Radar	4	4	5	150	4	13	6	27	2	80	10	20
Night Vision	2	2	20	20	5	6	15	15	15	15	20	40
Radar Warning Receivers	3	4	30	300	7	14	21	29	10	90	2	80
Missiles	3	4	117	450	4	5	14	31	15	120	30	50
Spacecraft Command and Control	4	6	150	300	5	6	21	29	10	600	13	20
Tactical Command and Control	12	16	5	850	5	20	7	30	20	6500	1	15
Torpedoes	3	3	142	350	2	4	2	14	15	30	51	60

The percentage of market share columns can exceed 100% overall because a firm may make a specific product line within an application area. For example, the ground control vehicle application area includes companies that make distinct products such as tanks or personnel carriers.

2. Characterization of the Business Units

2.1. Products

One way to characterize the firms participating is to describe the number of MCCR markets a firm supplies, the type of multiple product lines, if any, the firm produces, the extent to which sales of non-software components depend on the ability to supply the software, and the extent to which sales of non-software components influence the software contracts on which a business unit bids.

For the 51 business units in the 13 selected application areas, the number of MCCR markets supplied ranges from 8 to 450. Components in addition to the software are manufactured by 93% of the firms. Below are the percentages of respondents manufacturing various components.

- 60% Manufacture the computer hardware on which the software runs.
- 39% Manufacture peripheral equipment.
- 17% Manufacture a weapon system platform.
- 18% Manufacture some other component, such as:
 - Test equipment.
 - Computer based training.
 - Payloads.
 - Expendable decoys or compressors.

According to 55% of the respondents, sales of non-software products depended on the ability of firms to supply the software; 43% said that potential sales of non-software products influenced the choice of software contracts on which they bid.

2.2. Research and Development Expenditures

The average research and development (R&D) expenditures of the participating firms were about \$38 million with a standard error¹ of \$26 million. R&D expenditures represent an average of 5.3% of business unit revenues. An average of 28% of the R&D budget is spent on software development and 29% of the software research budget is directed toward developing Ada capabilities. Business unit R&D funds used for software development come from the following sources:

¹A standard error is a measure of the variability of the mean of a distribution.

- 56% From independent research and development (IR&D) funds.
- 27% From contract awards.
- 16% From company sponsored funds.
- 1% From other sources.

2.3. Contracts Characterized

These contract terms are commonly in use among the 51 organizations for the development of software systems:

- 60% Firm fixed price.
- 11% Cost plus award fee.
- 9% Cost plus fixed fee awards.
- 7% Cost plus incentive.
- 6% Fixed price plus incentive.
- 7% No response.

The average dollar value of a contract over the last three years ranges from some small contracts (less than 1 million dollars) in night vision and ground surveillance radar to the very large contracts (over \$100 million and up to \$650 million) in ground surveillance radar, attack radar, missiles, tactical command and control, and torpedoes. The dollar value of contracts is thought to have decreased in value since 1985 in missiles and spacecraft command and control. The dollar value of contracts is thought to have increased in the other 10 application areas. Flight control was named as an application where some respondents felt the dollar value of contracts had increased and others thought it had decreased. Over the next three years, the dollar value of contracts is expected to decrease in the areas of attack radar and missiles. Increases in the dollar value of contracts are expected by 67% of the responders and decreases are expected by 33% in ground surveillance radar, radar warning receivers, and flight trainers/simulators. In both spacecraft and tactical command and control, 50% of the respondents felt that the dollar value of contracts would increase over the next three years and 50% thought the dollar value would decrease. Increased expenditures are expected in the areas of aircraft engines, flight control, and night vision. Ground control vehicles, display processors, and torpedoes expect the dollar value to remain about the same as it is now.

The majority, 65%, said that from 2 to 10 contracts had been awarded over the last three years in their application areas. The range on the number of contracts awarded was from 0 to 30; 21 individuals did not know how many contracts had been awarded. New programs are started in a range from every 4 months up to every 30 years; however, 40% of respondents reported new programs are started every 1 to 3 years.

According to 53% of respondents, a delivered system is expected to be in a customer's operational inventory for about 15-20 years. Some systems are expected to remain only 5 years and others as long as 40 years. The current percentage of project cost that is attri-

buted to the development of software is from 5% to 80%, with a mean of 37%. Three years ago the mean was 30% and three years from now it is expected to be about 43% of the project cost. Regardless of the value cited, all expect the percentage of cost attributed to software to increase in the next three years.

When asked to name the percentage of expenditures over the lifetime of a system that might be spent on the initial development and production of the software, and the percentage that would be spent on modification, enhancements, and maintenance, individuals reported a wide range of values. The values reported ranged from 15% for initial development and 85% for modification up to 90% for initial development and 10% for modification.

2.4. Factors Influencing Contract Award

Individuals were asked to rate 10 factors that might influence their primary customer's choice of firm when awarding contracts. The factors were rated using a 7 point scale, where 1 meant "to no extent," and 7 meant "to a great extent." The factor rated of greatest importance in contract award was overall project cost, with proposed product performance, contractor experience in the application domain, and timeliness of projected product delivery as other variables that influenced the customer to more than a moderate extent in awarding contracts. Contractor software capability and projected software development cost were felt to exert a moderate influence. The factors thought to be of least importance in awarding contracts were software portability, ease of software maintenance, and expected cost of software maintenance. The factors and their mean rating were as follows:

Table 2-1: Rating of Contract Award Factors

Overall project cost	6.24
Proposed product performance	5.52
Contractor experience in area	5.50
Timeliness	5.30
Last contract an advantage	4.84
Project software development cost	4.63
Contractor software capability	4.44
Ease of software maintenance	3.41
Software maintenance cost	3.33
Software portability	2.91

Additionally, respondents reported that they did not think their primary customer would be willing to trade lower costs in the long run for greater costs during project procurement, further emphasizing the importance of short-term costs in contract award.

2.5. Technical Aspects of Products: Language, Response Mode, Interfaces, and Constraints

Languages used most over the last three years were reported to be Assembly, Ada, Fortran, C, Jovial, and Pascal. Operational software ran on an average of 7 processors, with the range being from 2 to 40. There were an average of 160,000 Delivered Source Instructions (DSI) in the operational software and an average of 6 Computer Software Configuration Items (CSCI)² per project. The number of CSCI ranged from 1 to 43.

Other software characterizations are presented below with a format of question asked and then a summary of the percentage of respondents choosing each option.

Which description best characterizes the required system response mode of operational software?

- 88% Real time: Software must complete processing in response to an event prior to the occurrence of the next event. Arrival of the data and occurrence of events is not under the control of the software.
- 7% Online software must respond within human compatible time frame, usually within seconds.
- 5% Time constrained: Software must complete processing within a specified time frame. Time lines are on the order of minutes to hours; sometimes a clock time is specified for process completion.

Which description best characterizes the effect of failure in the operational software?

- 51% The effect can be the loss of human life.
- 22% The effect is a moderate loss to users, but a situation from which one can recover with moderate penalty.
- 22% The effect can be a major financial loss or a massive human inconvenience.
- 3% The effect is a low level, easily recoverable loss to users.
- 2% The effect is simply the inconvenience required of the developers to fix the fault.

²The reported mean of 6 CSCI and the range of CSCI was calculated after withholding one value of 2500 CSCI.

Which description best characterizes the complexity of the interfaces?

- 57% Interfaces are moderately complex.
- 25% Interfaces are very complex; implementation of module design generally requires extensive knowledge of the implementation and design of other modules.
- 18% Interfaces between software modules are simple and direct.

Which description best characterizes the measures that your firm takes to deal with processing constraints in the development of operational software?

- 50% Performance analysis considerations are standard; usually addressed in the design phase.
- 35% Performance analysis considerations are standard; considerations generally require extensive use of analysis tools for both the design and the development of the software.
- 10% Performance analysis considerations are standard; usually addressed during later stages of development—for example, during validation and testing.
- 5% No or limited performance analysis considerations are needed.

The typical percentage of available processor execution time used by operational software is:

- 23% <50%
- 38% 50% - 70%
- 19% 71% - 85%
- 16% 86%- 95%
- 3% >95%

Typical percentage of processor main storage used by the operational software is:

18%	<50%
42%	50% - 70%
25%	71% - 85%
9%	86% - 95%
5%	>95%

Measures used to deal with memory constraints in the development of operational software:

38%	Some overlaying or segmentation
27%	No memory constraints
24%	Complex memory management and economic measures
11%	Extensive overlaying and segmentation

2.6. Software Process: Practices and Procedures

Technical personnel were asked to describe the software development process of their projects in two ways. One question asked them to select a description that best characterized the general software development process of their business unit. The descriptions correspond to the five levels of software process maturity described by Humphrey in *Characterizing the Software Process: A Maturity Framework* [Humphrey 89]. The other way of describing the software development process consisted of a set of 20 questions³ selected from *A Method for Assessing the Software Engineering Capability of Contractors* [Humphrey 87]. The responses to the 20 questions were combined into an overall software development score, where 20 would be the highest score, corresponding to an interpretation of adequate high-level software development practices.

A "yes" answer to a question indicates that the procedure or activity is one that the business unit uses in its software development process. The percentage of the 68 respondents falling within specific ranges is as follows:

53%	11-15 questions answered yes
37%	16-20 questions answered yes
10%	10 or fewer questions answered yes

On the descriptor chosen as characterizing the software development process and the total score on the 20 process questions, results were similar. Those who characterized the development process as less mature had lower process scores and those who characterized the software development process as fairly mature had higher process scores. The mean,

³The 20 questions were selected from a total of 101 questions on two bases: (1) they represent the key practices adequately, and (2) they did well with respect to internal consistency.

standard deviation of the process score and number of people choosing each level of the maturity characterization is shown in Table 2-2.

Table 2-2: Process Score for Each Maturity Level

	<u>Mean</u>	<u>Standard Deviation</u>	<u>Number of Respondents</u>
Initial	10.7	4.07	14
Repeatable	14.3	2.57	35
Defined	15.7	3.17	12
Managed	18.7	2.31	3
Optimized	20.0	--	1

The items that were most frequently answered "no" and the percentage of individuals choosing that response were as follows:

1. Is a mechanism used for initiating error prevention action? (70%)
2. Is a mechanism used for error cause analysis? (69%)
3. Are the error causes reviewed to determine the process changes required to prevent them? (57%)
4. Is software productivity analyzed for major process steps? (52%)

Individuals were asked to compare the software development capabilities of their business unit with that of their competitors. The process score for the different comparisons were again similar, meaning that those who rated the capabilities of their business unit as somewhat below those of their competitors had lower process scores than those who rated the capabilities of their business unit as better than average. The values are summarized in Table 2-3.

Table 2-3: Software Development Capabilities

<u>Comparison to Competitor</u>	<u>Process Score</u>		
	<u>Mean</u>	<u>Standard Deviation</u>	<u>Number of Respondents</u>
Below Average	10.4	2.12	5
About Average	13.4	3.16	14
Better than Average	15.0	3.21	37

3. Ada Use

3.1. Primary Customer's Attitude

Business respondents were asked their perception of their primary customer's attitude toward the use of Ada for the development of software systems. The results were as follows:

- 55% Rate their customer as preferring Ada but willing to consider other languages.
- 17% Report that their customer insists on Ada.
- 17% Rate their customers as indifferent to language used.
- 11% Rate their customers as against or adverse to the use of Ada.

Respondents also gave their perceptions of their customer's attitude toward language use three years ago and three years in the future. There is a definite change in attitude toward language use across that time period. Approximately 45% of the customers were perceived as being adverse to Ada use three years ago, declining to only 2% expected to remain adverse to Ada three years from now. Respondents were further asked their expectation of the percentage of new development contracts for which Ada will be the required language in 1989, 1990, and 1991. While not as pronounced as the expectations of attitude toward language used, there is still an increase in the percentage of contracts expected to require Ada. Respondents expect 56% of their contracts to require Ada use in 1989, 67% in 1990, and 76% in 1991. They further estimated that during the past three years about 37% of the contracts had been awarded to companies proposing to use Ada as the primary implementation language.

3.2. Ada Use in the Business Units

Some other characteristics of the business units reported by the technical respondents are as follows:

- 85% Have proposed to use Ada as the primary implementation language
- 72% Have used an Ada PDL
- 71% Have built Ada software as part of an R&D project
- 69% Have been contracted to develop a system using Ada
- 34% Of the software development efforts within a business unit use an Ada PDL
- 28% Were funded by a customer for the R&D project

The number of Ada R&D projects undertaken per organization range from 1 to 25, with 35%

not responding. Of those who answered, 54% have done 1 or 2 projects, while 44% have done from 3 to 6 projects. Only one person responded that his business unit had undertaken 25 R&D projects. The range of lines of executable code (LOC) for the largest single Ada R&D project undertaken by the various business units was from 2,000 to 1,200,000 LOC. The average size was 78,000 LOC.

3.3. Ada Contracts

The year named, the number of respondents, and the application for the first contract awarded to a firm that proposed to use Ada as the primary implementation language was as follows:

1981	1	Tactical command and control (C ²)
1982	1	Tactical C ²
1983	2	Tactical C ²
1984	2	Night vision, spacecraft C ²
1985	5	Display processor, ground control vehicles, flight trainers, spacecraft C ² , tactical C ²
1986	7	Aircraft engines, tactical C ² , flight trainers
1987	5	Attack radar, torpedoes, missiles, flight control, spacecraft C ²
1988	8	Missiles, flight trainers, ground control vehicles, radar warning receivers, flight control, spacecraft C ²
1989	4	Flight control, radar warning receivers, spacecraft C ²

In addition to the numbers above, 10 (18%) said that as yet no contract had been awarded that required Ada as the primary implementation language and 18% said they didn't know when the first contract requiring Ada had been awarded in their application area. For this group of respondents, the first Ada contracts were awarded in the area of tactical command and control. It was reported that in 1988 an Ada contract was awarded in the radar warning receivers area. This information on contracts requiring Ada use, also gives an indication that Ada is being used in a variety of application areas.

3.4. Ada Trained Personnel

Technical personnel were asked how much more difficult it was to hire technical staff with Ada capabilities. They reported that it is moderately difficult to hire programming staff and much more difficult to hire software/systems designers with Ada capabilities. When asked how much of a salary premium, if any, is commanded by newly hired staff with Ada capabil-

ities, 35% of the respondents said a premium would be paid. The average value of the premium reported was 12%, with a range from 5% to 40%. Conversely, 65% of the respondents said no salary premium would be paid for Ada capabilities. Several respondents also commented that experience in the application area was equally important and necessary.

3.5. Expected Effects of Ada Use During Production

Respondents were asked their expectations of the effect of Ada use on time and cost changes at specific development stages. Since responses were very similar for time and cost they are reported together. Respondents expect that more time and cost will be required during top-level design and detailed design stages. Time and cost are expected to be less during full-scale development, integration and test, and production support. Code and unit test are expected to take about the same time and cost as development in another language. The respondents categorized the expected effect of Ada use on overall time and overall cost to develop a system as follows:

Overall Effect on Time

- 33.3% Expect the time required to decrease an average of 24%.
- 33.3% Expect the time required to increase an average of 18%.
- 33.3% Expect the time required to about the same as in another language.

Overall Effect on Cost

- 33.3% Expect the cost to decrease an average of 21%.
- 33.3% Expect the cost to increase an average of 19%.
- 33.3% Expect costs to be about the same.

Other Expected Effects of Ada Use

Compared to similar systems implemented in other languages:

- 75% Expect that Ada will decrease overall post-development support costs by an average of 25%.
- 74% Expect that the number of Class II errors will be lower.
- 73% Expect that the number of Class I errors will be lower.
- 59% Expect that Ada direct labor costs will be lower.

3.6. Acquisition of Ada Tools and Use of Ada Features

An Ada compiler was first acquired in 1981 by one of the firms; however, 93% first acquired an Ada compiler between 1983 and 1988. Among respondents, 43% acquired the compiler for a specific project, but 57% did not. The compiler was sufficiently mature and could be used without customization at the time of its first use for 24% of the respondents. The Ada

compilers were reported as validated when first acquired by 65% of the respondents. Adequate Ada vendor support was reported by 70% of respondents, and 22% have established some kind of long-term relationship with an Ada vendor.

Technical individuals whose business units have designed or developed a system in Ada were asked the extent to which they found certain features of Ada useful. The features asked about were:

- Generics
- Packages
- Private types
- Derived types
- Access types
- Exceptions
- Record types

Those cited as being used more than moderately were record types and packages. The least used feature was generics. Of the respondents, 47, or 72%, used all 8 of the Ada language features and can be considered adopters of Ada. Of the 47 respondents, 41 also gave the month and year they had started to develop Ada capabilities in their staff and had acquired an Ada compiler. Of those supplying the time information, 42% trained staff before acquiring an Ada compiler. There were 31 technical respondents who supplied month and year data for acquiring a compiler and for the first proposal to use Ada. It was surprising to note that 25% had proposed to develop a program in Ada before acquiring a compiler. This observed time sequence differs somewhat from a supposed adoption model of acquiring a compiler, training staff, proposing to develop a project, and receiving a contract.

Respondents were asked for the percentage of new development contracts they are implementing in Assembly, Ada, and other high-order languages and for the percentage of new development contracts they propose to develop in those languages. The results are shown in Table 3-1.

Table 3-1: Language Used and Proposed for New Contracts

	<u>Implemented</u>	<u>Proposed</u>
Ada	50%	66%
Assembly	15%	11%
Other	35%	23%

The other languages used and proposed for use in order of decreasing frequency cited were C, Fortran, Pascal, and Jovial.

3.7. Comparison of Ada Compilers With Other Compilers

Respondents were asked for their opinion of Ada compilers and tools compared to other available compilers and tools at three points in time:

- Three years ago.
- At the present time.
- Three years from now.

They rated the comparable quality using a 7 point scale where "1" meant significantly inferior, "4" meant approximately the same, and "7" meant significantly superior.

The average rating of Ada compilers or tools compared to other compilers or tools at three time periods is shown in Table 3-2.

Table 3-2: Mean Rating of Ada Compilers or Tools

<u>Compared to Other</u>	<u>3 Years Ago</u>	<u>Now</u>	<u>3 Years from Now</u>
Ada Compilers	1.73	3.61	5.17
Ada Tools	1.75	3.52	5.16

When they compared today's Ada compilers and tools to Ada compilers and tools available at two other time periods the ratings were 1.57 for three years ago and 5.56 for three years in the future. Thus it seems that Ada compilers and tools have improved from three years ago, that they are now viewed as of comparable quality to other compilers and tools, and that it is expected that they will be somewhat superior to other compilers and tools three years from now.

3.8. Comparison of Units With and Without Ada Contracts

A further indication of the extent of Ada acceptance is that all but 4 (7%) business units own an Ada compiler. Only 3 (5%) say they have not developed Ada capabilities in their staff, and only 5 (9%) have not proposed to build a system in which Ada is the primary implementation language. At present, 37 (70%)⁴ of all business units responding have been awarded a contract to develop a system using Ada as the primary implementation language. Of those 37 contractors with an Ada contract, 37% considered the Air Force their primary customer, 35% considered the Navy their primary customer, and 17% considered the Army their primary customer. The other contractors either deal equally with all branches, another DoD or federal agency or work primarily in the commercial market. The market share of those with Ada contracts range from 2% to 60% with a mean of 19%.

⁴This figure differs from the 69% reported by the technical respondents on page 17 because of the difference in the number of respondents in each group.

Of the 16 contractors who have not yet been awarded an Ada development contract, 5 are in either the radar warning receivers or torpedoes application areas. The other business units not having an awarded contract in Ada are scattered across the other application areas. Of those without an Ada contract, 24% consider the Air Force as their primary customer, 18% consider the Navy their primary customer, and 12% consider the Army their primary customer. The market share of this group in their respective application areas ranges from 5% to 80% with a mean of 30%.

Several other variables were examined to see if there were any differences between those who have Ada contracts and those who do not. A summary of six variables on which the two groups differed follows.

For the group with contracts:

1. The average dollar value of a contract is \$54 million.
2. An average of 8 new contracts was awarded in the last 3 years.
3. New programs are started on an average of every 37 months.
4. A system remains in the customer's inventory about 17 years.
5. The average cost of an Ada compiler, linker, and loader is \$95,000.
6. 31% of the software staff have experience developing Ada software systems in the application area.

For the group without Ada contracts:

1. The average dollar value of a contract is \$83 million.
2. An average of 5 new contracts per year were awarded in the last 3 years.
3. New programs are started on an average of every 75 months.
4. A system remains in the customer's inventory about 21 years.
5. The average cost of an Ada compiler, linker, and loader is \$67,000.
6. 10% of the software staff have experience developing Ada software systems in the application area.

The cost (purchase price, plus the cost of customization) to acquire a production quality Ada compiler, linker, and loader was from a minimum of \$8,000 up to a maximum of \$300,000 for those with an Ada contract and from a minimum of \$8,000 to a maximum of \$150,000 for those without a contract.

The variables examined on which the two groups did not differ were:

1. The turnover rate of their software personnel.
2. The rating on their group's software process capabilities.
3. The percentage of the project cost attributed to software.
4. The primary customer's attitude toward Ada use.
5. The percentage of software personnel receiving their Ada training in courses sponsored or paid for by the firm.
6. The percentage of software personnel that can design and code in Ada.
7. The cost to train staff to design and implement in Ada.

Correlations were calculated between firm size, market share, primary customer, number of competitors, and having or not having an Ada contract. The results indicated:

1. A significant correlation between:
 - Number of competitors and percentage of Army contracts, $r = .44$.
 - An Ada contract and market share, $r = -.49$.
2. Some, but not a significant relationship between:
 - Number of competitors and an Ada contract, $r = .30$.
 - Number of competitors and market share, $r = -.32$.
3. There was no correlation between:
 - Firm size variables and an Ada contract.
 - Firm size and market share.
 - Primary DoD customer and an Ada contract.

The conclusion from these calculations is that:

1. Firms with the larger market share tend not to have an Ada contract.
2. Firms with more competitors tend to have Ada contracts.
3. Having an Ada contract is not related to firm size variables or primary customer.

In summary, the characterization of firms with Ada contracts, when compared to those without contracts, is that firms with Ada contracts operate in a more competitive arena, where contracts have lower dollar value, and are awarded more frequently for systems that stay in the customer's inventory an average of 4 fewer years. Further, firms with Ada contracts have a larger percentage of staff with experience developing Ada software systems in the application area.

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Appendix A: Overview of Ada and MCCR Software

Nominally, Ada is a general purpose programming language⁵. Like other programming languages, it is a collection of syntactical rules, constructs, functions, abstractions, etc., that can be used to model a problem and its solution. Ada is unlike other languages, however, in the degree to which it fosters and supports the practice of software engineering principles.⁶ These design principles are believed to lower software development costs, increase software quality, and lower maintenance costs, especially for large or complex systems. In effect these features and the structure of the language make it easier to develop software that is more understandable and more maintainable.⁷

In addition to being another programming language, Ada is also being promoted as the standard language for the largest class of DoD software applications. Standardization on a handful of high-order languages (HOLs) for the development of military software was expected to have at least three major benefits for the DoD. First, software personnel in both the DoD and its contractors had become fragmented over the large number of languages.⁸ This meant that software professionals were not readily able to move from project to project. Second, the proliferation of languages meant that the DoD had great difficulty transporting software across computer environments. In addition to the costs of rehosting software, the diversity of development languages meant that the DoD could not readily utilize the software that it already had as a capital stock of predeveloped, pretested software components available for reuse in other systems. Finally, the large number of languages meant that few commercial software tools were available for any given language. Just as software professionals had become fragmented, the efforts of tool suppliers were being spread across numerous small language markets. If the DoD, itself a consumer of considerable amounts of software, could limit the number of languages it used, tools vendors would have relatively larger markets on which to concentrate their efforts. Presumably, with bigger potential markets these vendors would have incentives to produce more and better tools for the DoD and its contractors. In summary, the DoD foresaw significant savings in the personnel, tools, software reuse, and training if the number of languages it supported were reduced.

⁵Ada is defined in ANSI/MIL-STD-1815A.

⁶Specifically, the language was designed and developed to support structured constructs, strong typing, relative and absolute precision specification, information hiding and abstraction, concurrent processing, exception handling, generic definition, and machine-dependent facilities.

⁷Although the language does have constructs that support requirements such as exception handling, it is reasonable to assume that the greatest benefits that may come from using Ada are not because of the language *per se*, but because it facilitates more disciplined software development practices. It is important to note that while Ada is a tool that fosters better development practices, the language itself neither makes a programmer into software engineer, nor does it automatically increase the "quality" of software. It is possible to use Ada syntax without producing a well engineered system. In a very real sense, the effect that Ada use will have on software costs and quality depends on firms' abilities to exploit the features of the language.

⁸In 1973, it was estimated that the DoD was using and maintaining systems written in 450 different languages and dialects. Further, half of these were assembly languages.

Mission-Critical Computer Resource (MCCR) covers a wide range of applications from small systems used to monitor engine performance to multi-million line systems used to coordinate military commands across the globe.⁹ If we were to characterize the software in these systems in general, it tends to be large, real-time, long-lived, and subject to continuous change. In addition, because of the environments in which it operates, MCCR system software must almost always be highly fault tolerant, and the systems themselves are frequently hardware resource constrained. Together, characteristics of the software (large, processing and communication intensive) and characteristics of the environment (long operating life, constant change, high cost of software failure, resource constrained) put severe demands on MCCR software performance, and in turn, on suppliers of these systems. Ada's development was initiated and sponsored largely in response to the DoD's perceived need for a tool with which software contractors could better meet the increasing demand for and stringent requirements of this large and important class of systems.

However, the accelerated adoption of Ada in MCCR applications is not simply a function of its demonstrated or expected technical superiority over languages that are currently being used by contractors. In part, firms are also reacting to a DoD policy that mandates Ada use for the development of MCCR applications. Because of this policy, firms that develop MCCR products have had to carefully evaluate Ada in light of its potential effects as both a new production process and as a new product. While the policy has made contractors aware of Ada, the effect that the mandate has had on determining firms' adoption decisions should not be overstated. The policy has not established a uniform demand for Ada systems across MCCR product markets. Implementation of the DoD directive at the operational level has shown a great deal of variance in customers' demand for, or even willingness to consider, systems written in this relatively new and unproven programming language. As a consequence, firms have been evaluating, adopting, and not adopting Ada in a large variety of markets and technical environments.

1.a. Procurement of Military Software

Military procurement is generally defined by the weapon system life cycle and the type of contract terms. The weapon system acquisition life cycle is a five phase process with a contract typically awarded at the beginning of each phase. The phases, concept exploration, demonstration and validation, full-scale development, production, and deployment, are nominally separate steps, although some overlap of phases may occur.

Concept exploration: This initial phase in the acquisition process is preceded by the identi-

⁹MCCR is properly defined in DoD Directive 5000.29 to include the following applications: intelligence activities, cryptologic activities for national security, command and control, equipment integral to a weapon system (i.e., embedded systems), and resources critical to military and intelligence missions. Computers integral to weapon systems are described as follows: (a) physically a part of, dedicated to, or essential in real-time to a performance of the mission of a weapon system, (b) used for specialized training, diagnostic testing and maintenance, simulation, or calibration of weapons systems, (c) used for research and development of a weapon system.

cation and approval of a mission that is not adequately being met by the present systems. In the concept exploration phase a number of alternatives for meeting the mission need are developed and explored. Alternative solutions include not only the development of new systems, but also the modification of existing equipment. Recommendations in the form of a written document are then passed up the chain of command for consideration. The final review and decision to continue to the next phase is called Milestone I.

Demonstrations and Validation: If the decision at Milestone I is to continue development of a new system, the program moves to the demonstration and validation phase. The purpose of this phase is to further define alternatives developed in concept exploration. Definition usually involves paper studies, but in the extreme may include the development of complete working prototypes of competing alternative designs. During this phase, source selection between two or more competing contractors is made. Milestone II, a review process, ends this phase.

Full-Scale Development (FSD): During FSD all equipment essential for the manufacture and maintenance of the system is designed, fabricated, and tested. The outcome of the FSD phase is the production of one or more preproduction models of the proposed system. It is during this phase that the system software is developed and tested. After FSD, the program is again reviewed and a decision is made to cancel or to go to full production of the program. At this time, Milestone III, a decision is made about the number of systems to be produced.

Production/Deployment: The final two stages of the process are as their names imply. A series of contracts for production lots may be awarded over the production lifetime of the system. Recently, DoD has made a concerted effort to give production contracts to more than one contractor in order to maintain some level of competition for contracts. In deployment, the systems and all supporting equipment are turned over to the command units for their use.

At any one of these phases a contractor may be eliminated from contract competition. Once a contractor is eliminated, it is difficult, though not impossible, to become involved in subsequent stages of that particular project.

1.b. Contract Types

DoD contracts for weapon system procurement generally are either fixed price or cost reimbursement.

Fixed-price contracts are used when contract performance costs can be accurately estimated ex ante, and when the terms for contract completion are sufficiently specific. In the extreme firm fixed-price contract, the contractor agrees to deliver a specified item(s), at a specified time, and for a specified price. Variants of the fixed-price contract exist in which the contractor and the DoD share realized cost savings or overruns.

Cost-reimbursement contracts are used when cost, performance, or schedule uncertainties for contract completion are more significant. Under the terms of a cost-reimbursement contract, the DoD agrees to pay some portion of the contractor's project related expenses, plus a fixed or variable fee.

The type of contract used for a procurement is dictated by the DoD, and is a function of the anticipated risks of contract completion. As risks increase, the DoD tends to take a greater share of the risks through the use of cost-reimbursement contracts. Almost by definition, shifting the burden of risk between the contractor and the DoD can significantly change the contractors' incentives as well as their exposure to risk.

Appendix B: Questionnaires

Technical Questionnaire

A. Application Software Information: Questions on the next three pages are intended to elicit a general characterization of (APPLICATION AREA) software and systems. Your answers should reflect, as best as possible, estimates based on recent (APPLICATION AREA) systems with which you are familiar.

A.1. Languages and Processors:

1. Over the last three years, what three languages has your business unit used most to develop software for (APPLICATION AREA) systems?: (please list in decreasing order of use; if assembly language, please indicate processor)

(a). _____

(b). _____

(c). _____

2. For what three target processors (e.g. 1750A, 68010, 80286) has your firm's (APPLICATION AREA) business unit developed the most software over the past three years?: (please list in decreasing order of use)

(a). _____

(b). _____

(c). _____

3. In the operating (target) environment, does the (APPLICATION AREA) software that your firm develops run on multiple processors?: Yes: _____ No: _____

If No: Please skip to the top of the next page.

If Yes: Please answer 3.a. and 3.b..

3.a. Disregarding the types of processors, on approximately how many total processors does (APPLICATION AREA) operational software run?: _____

3.b. Which of the descriptions below best characterizes the degree of coupling between processors in (APPLICATION AREA) systems?: (choose one)

____: Processors are independent with each having its own memory and storage resources.

____: Processors are largely independent, but share some global memory.

____: Processors are coupled by sharing common memory and/or storage.

____: Processors are coupled by passing messages (e.g. task completion).

____: Processors are coupled through shared tasks.

____: Other (please briefly describe): _____

____: Don't Know

A. Application Software Information: (cont'd)

A.2. Software Size/ Effects on Software Design:

1. Approximately, how many Delivered Source Instructions are there in the operational software for a (APPLICATION AREA) system?: _____

2. Approximately, into how many Computer Software Configuration Items (CSCI) is the operational software in a (APPLICATION AREA) system divided?: _____

3. What is the typical percentage of available processor execution time used by operational software in (APPLICATION AREA) systems?: (choose one)

- ___: < 50%
- ___: 50% - 70%
- ___: 71% - 85%
- ___: 86% - 95%
- ___: >95%
- ___: Don't Know

4. Which of the descriptions below best characterizes the measures that your firm takes to deal with processing constraints in the development of operational software for (APPLICATION AREA) systems?: (choose one)

- ___: No or limited performance analysis considerations are needed.
- ___: Performance analysis considerations are standard; usually addressed during latter stages of development (e.g. validation and testing stages).
- ___: Performance analysis considerations are standard; usually addressed in the design phase.
- ___: Performance analysis considerations are standard; considerations generally require extensive use of analysis tools for both the design and the development of the software.
- ___: Don't Know

5. What is the typical percentage of processor main storage (i.e., direct random access storage) used by the operational software in (APPLICATION AREA) systems?: (choose one)

- ___: < 50%
- ___: 50% - 70%
- ___: 71% - 85%
- ___: 86% - 95%
- ___: >95%
- ___: Don't Know

6. Which of the descriptions below best characterizes the measures that your firm takes to deal with memory constraints in the development of operational software for (APPLICATION AREA) systems?: (choose one)

- ___: No memory constraints.
- ___: Some overlaying or segmentation.
- ___: Extensive overlaying and segmentation.
- ___: Complex memory management and economic measures.
- ___: Don't Know

A. Application Software Information: (cont'd)

A.3. Software Complexity:

1. Which of the descriptions below best characterizes the required system response mode of operational software for (APPLICATION AREA) systems: (choose one)

- ☐: Non-time critical: No time constraint for the completion of processing.
- ☐: Time-constrained: Software must complete processing within a specified time frame. Time lines are on the order of minutes to hours; sometimes a clock time is specified for process completion.
- ☐: On-line: software must respond within human compatible time frame, usually within a few seconds.
- ☐: Real-time. The software must complete processing in response to an event prior to the occurrence of the next event. Arrival of the data and occurrence of events is not under the control of the software.
- ☐: Don't Know

2. Which of the descriptions below best characterizes the effect of failure in the operational software for (APPLICATION AREA) systems?: (choose one)

- ☐: The effect of a software failure is simply the inconvenience required of the developers to fix the fault
- ☐: The effect of a software failure is a low level, easily recoverable loss to users.
- ☐: The effect of a software failure is a moderate loss to users, but a situation from which one can recover with moderate penalty.
- ☐: The effect of a software failure can be a major financial loss or a massive human inconvenience.
- ☐: The effect of a software failure can be the loss of human life.
- ☐: Don't Know

3. Which of the descriptions below best characterizes the complexity of the interfaces in the (APPLICATION AREA) software that your firm develops?: (choose one)

- ☐: Interfaces between software modules are simple and direct; implementation of software module design can usually be done with only highly abstracted knowledge of other software modules.
- ☐: Interfaces between software modules are moderately complex; some knowledge of other software modules' design is often needed in order to implement software module design;
- ☐: Interfaces between software modules are very complex; implementation of software module design generally requires extensive knowledge of other modules' implementation as well as their designs
- ☐: Don't Know

4. Over the lifetime of a (APPLICATION AREA) system, what percentage of DoD expenditures for system software may be expected to be for:

- ☐ %: Initial Development/Production of Software up to its Acceptance/Deployment
- ☐ %: Modifications, Enhancements, and Maintenance of the Software after Initial Acceptance/Deployment

B. Software Development Organization: In this section we ask questions intended to get a general picture of the software personnel and procedures in the part of your firm that produces software for (APPLICATION AREA) systems.

1. Approximately, how many software personnel are currently employed by your firm's (APPLICATION AREA) business unit? _____ (do not include temporary personnel that may be contracted to cover peak staffing on projects)

2. Approximately, how many software personnel were employed by your firm's (APPLICATION AREA) business unit three years ago? _____ Don't Know: _____ Not Applicable: _____

3. What percentage of the software personnel in your firm's (APPLICATION AREA) business unit have earned the following university degrees with majors in Computer Science, Electrical Engineering, Computer Engineering, Information Science, or Software Engineering? What percentage have degrees in other majors or no degrees? (the summation of percentages should be approximately equal to 100)

_____ %	PhD/Doctorate	Majors in Computer Science, Electrical Engineering, Computer Engineering Information Science, Software Engineering
_____ %	MS/Masters	
_____ %	Bachelors	
_____ %	Degrees in other majors;	
_____ %	No degree	
_____ ≈ 100 %		

4. What percentage of the software development staff in your firm's (APPLICATION AREA) business unit have the following years of industry software development experience? (the summation of percentages should be approximately equal to 100)

_____ %	0 - < 2 years
_____ %	2 - < 4 years
_____ %	4 - < 6 years
_____ %	6 - < 8 years
_____ %	8 - < 10 years
_____ %	10 years or more
_____ ≈ 100 %	

5. What is the average tenure (years employed by your company) of the software development staff in your business unit? (choose one)

_____	0 - < 2 years
_____	2 - < 4 years
_____	4 - < 6 years
_____	6 - < 8 years
_____	8 - < 10 years
_____	10 years or more

5.a. How does your business unit's turnover rate of software personnel compare to the firms with which you compete for (APPLICATION AREA) development contracts? Is the turnover rate in your firm's (APPLICATION AREA) business unit: (choose an integer from 1 to 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

Significantly Lower than Average				About Average			Significantly Higher than Average		
1	2	3	4	5	6	7	D/K	N/A	

B. Software Development Organization: (cont'd)

B.2. Business Unit Software Practices and Procedures: To the right of each question below are four responses: "YES", "NO", "Don't Know", and "Not Applicable". As you read each question, consider how it pertains to recent (APPLICATION AREA) projects with which you are familiar. If you feel the practice referenced in the question is generally a part of the software development procedures in your firm's (APPLICATION AREA) software development projects, choose "YES". If the practice is not generally part of software development procedure, choose "NO". If you do not know if a practice is generally part of software development procedures for projects, choose "D/K". If you feel that a question is not applicable to software developments, or if you do not understand a question, choose "N/A".

(a) Is there a software configuration control function for projects that involve software development?:	YES	NO	D/K	N/A
(b) Is a mechanism used for managing and supporting the introduction of new technologies?:	YES	NO	D/K	N/A
(c) Does the software organization use a standardized and documented software development process on projects?:	YES	NO	D/K	N/A
(d) Are standards used for the content of software development files/folders?:	YES	NO	D/K	N/A
(e) Are coding standards applied to software development projects?:	YES	NO	D/K	N/A
(f) Are internal design review standards applied to software development projects?:	YES	NO	D/K	N/A
(g) Are code review standards applied to software development projects?:	YES	NO	D/K	N/A
(h) Are profiles maintained over time of actual versus planned software units completing unit testing?:	YES	NO	D/K	N/A
(i) Are target computer memory utilization estimates and actuals tracked?:	YES	NO	D/K	N/A
(j) Are the action items resulting from code reviews tracked to closure?:	YES	NO	D/K	N/A
(k) Is a mechanism used for error cause analysis?:	YES	NO	D/K	N/A
(l) Are the error causes reviewed to determine the process changes required to prevent them?:	YES	NO	D/K	N/A
(m) Is a mechanism used for initiating error prevention action?:	YES	NO	D/K	N/A
(n) Is software productivity analyzed for major process steps?	YES	NO	D/K	N/A
(o) Does senior management regularly review the status of software development projects?	YES	NO	D/K	N/A
(p) Is a mechanism used for periodically assessing the software engineering process and implementing indicated improvements?:	YES	NO	D/K	N/A
(q) Is a mechanism used for ensuring compliance with the software engineering standards?:	YES	NO	D/K	N/A
(r) Is a mechanism used for controlling changes to the software requirements?:	YES	NO	D/K	N/A
(s) Is a mechanism used for ensuring traceability between the software detailed design and the code?:	YES	NO	D/K	N/A
(t) Is a mechanism used for controlling changes to the code?: (i.e., who can make changes under what circumstances)	YES	NO	D/K	N/A

B. Software Development Organization: (cont'd)
B.2. Business Unit Software Practices and Procedures: (cont'd)

2. Of the five descriptions below (A-E), which most accurately characterizes your business unit's general software development environment?: (choose one)

___A. Procedures and controls over software development efforts are loosely defined and are applied on a project by project basis. The software development process varies widely between projects.

___B. Standard methods and practices are uniformly applied to development efforts. The management of software development includes cost and schedule estimation, control of requirements changes, code changes and status reviews. Development procedures used by different groups within the business unit would be approximately the same.

___C. The software development process is defined and understood. Projects regularly conduct design and code reviews, training programs for project leaders and programmers with specific focus on software engineering principles and practices. The development process is reviewed by a software engineering process group that suggests changes in practices and procedures.

___D. The software development process is understood, quantified, measured, and controlled. Operating decisions are based on quantitative process data that has been gathered during software reviews and tests. Tools are frequently used to manage the design process, including the gathering and analysis of data.

___E. The software development process is highly controlled and there is a considerable effort to further improve the process through extensive cost, scheduling, and error analyses of current and past projects. Quantitative data from past projects are routinely used to identify and eliminate processes that are prone to introduce errors.

3. Which of the five descriptions above most accurately characterizes your business unit's general software development environment three years ago? (choose one letter (A-E), "D/K" for Don't Know, or "N/A" for Not Applicable)

A B C D E D/K N/A

4. Compared to the firms with which you compete for (APPLICATION AREA) software development contracts, how would you rate your business unit's software development capabilities? Are your business unit's software development capabilities (choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

Significantly Worse than Average				About Average			Significantly Better than Average		
1	2	3	4	5	6	7	D/K	N/A	

Section C. Ada and Personnel:

C.1. Ada and Personnel: In Your Firm's (APPLICATION AREA) Business Unit

1. Has your business unit developed (via new hires or training programs) Ada capabilities in your software development staff? Yes: _____ No: _____ Don't Know: _____

If No or Don't Know: Please skip to question 2

If Yes: Please answer questions 1.a. through 1.e.

1.a. Approximately, when did you begin to develop Ada capabilities in your business unit's software development staff?

_____(month)_____(year)

1.b. Of the Ada trained software personnel in your business unit, what percentage received their primary Ada training in courses sponsored or paid for by your firm: _____%

1.c. Currently, what percentage of all software personnel in your business unit have enough training in Ada such that they could be used to generate code on an Ada software development program?: _____%

1.d. Currently, what percentage of all software designers in your business unit have enough training in Ada such that they could develop designs for an Ada software development program?: _____%

1.e. Currently, what percentage of your software staff has experience developing Ada software systems in the (APPLICATION AREA) domain?: _____%

2. Approximately, what do you expect is the per capita cost to train your software personnel to design and implement (APPLICATION AREA) software systems in Ada?: \$ _____/person Don't Know: _____

C.2. Ada and Personnel: External Labor Markets

1. Compared to software personnel with otherwise similar abilities and experience, how much more difficult is it to hire programming staff and software/system designers with Ada capabilities? (choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

	No More Difficult		Moderately More Difficult			Significantly More Difficult			
(a) Programming Staff:	1	2	3	4	5	6	7	D/K	N/A
(b) Software/System Designers:	1	2	3	4	5	6	7	D/K	N/A

2. How much of a salary premium is commanded by programming staff and software/system designers with Ada capabilities? (please estimate to nearest 5%)

(a) On average, programming staff with Ada capabilities may expect _____% of the salary of programming staff with otherwise similar abilities and experience.

(b) On average, software/system designers with Ada capabilities may expect _____% of the salary of software/system designers with otherwise similar abilities and experience.

Section D. Ada Compilers/Tools:

D.1. Ada Compilers and Tools: Comparisons with Other Languages- Questions in subsection D.1. ask for comparisons of Ada compilers and tools versus compilers and tools for languages that your business unit might otherwise use to develop (APPLICATION AREA) software. We ask for comparisons at three different times: now, three years in the past, and your expectations for three years in the future. Using the seven point scale below, where 1 means "Significantly Inferior", 4 means "Approximately the Same", and 7 means "Significantly Superior", please respond to the following questions.

1. How do available Ada compilers compare to available compilers for other languages used to develop (APPLICATION AREA) software?: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Inferior		Approximately the Same			Significantly Superior		
(a) At the present time, Ada compilers are:	1	2	3	4	5	6	7	D/K
(b) Three years ago, Ada compilers were:	1	2	3	4	5	6	7	D/K
(c) Three years from now, Ada compilers will likely be:	1	2	3	4	5	6	7	D/K

2. How do available Ada software tools compare to available software tools for other languages used to develop (APPLICATION AREA) software?: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Inferior		Approximately the Same			Significantly Superior		
(a) At the present time, Ada software tools are:	1	2	3	4	5	6	7	D/K
(b) Three years ago, Ada software tools were:	1	2	3	4	5	6	7	D/K
(c) Three years from now, Ada software tools will likely be:	1	2	3	4	5	6	7	D/K

D.2. Ada Compilers and Tools: Comparisons Over Time- Using the same seven point scale, please compare the Ada compilers and tools that are currently available to those available three years in the past, and your expectations of them three years in the future?

1. Compared to Ada compilers that are currently available: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Inferior			Approximately the Same			Significantly Superior		
(a) Three years ago, Ada compilers were:	1	2	3	4	5	6	7	D/K	
(b) Three years from now, Ada compilers will likely be:	1	2	3	4	5	6	7	D/K	

Section D. Ada Compilers/Tools: (cont'd)

D.2. Ada Compilers and Tools: Comparisons Over Time (cont'd)

2. Compared to Ada software tools that are currently available: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Inferior		Approximately the Same				Significantly Superior		
(a) Three years ago, Ada software tools were:	1	2	3	4	5	6	7	D/K	
(b) Three years from now, Ada software tools will likely be:	1	2	3	4	5	6	7	D/K	

D.3. Ada Compilers and Tools: Costs

Current Acquisition Costs

1. Approximately, what can a firm that builds (APPLICATION AREA) software expect to spend (purchase price, plus the cost of customization if needed) to acquire a production quality Ada compiler, linker, and loader?:

\$_____ Don't Know:_____

2. In addition to the costs of the minimal set of tools (compiler, linker and loader), how much can a firm that builds (APPLICATION AREA) software expect to spend on other Ada specific software development tools and additional computing facilities?: \$_____ Don't Know:_____

Acquisition Costs Over Time

3. Compared to Ada software tools (including compilers) that are currently available: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Less Expensive		Approximately the Same				Significantly More Expensive		
(a) Three years ago, Ada software tools were:	1	2	3	4	5	6	7	D/K	
(b) Three years from now, Ada software tools will likely be:	1	2	3	4	5	6	7	D/K	

Section D. Ada Compilers/Tools: (cont'd)

D.4. Ada Compiler(s): Acquisition by Your Firm's (APPLICATION AREA) Business Unit

1. Has your business unit acquired (e.g. purchase, lease, rent, time share, or develop) an Ada compiler?:

Yes: _____ No: _____

If No: Please answer question 1.a.

If Yes: Please answer questions 1.b. through 1.e.

- 1.a. Do you anticipate that your business unit will acquire an Ada compiler within the next 12 months?

Yes: _____ No: _____ Don't Know: _____

If you expect that your firm will acquire an Ada compiler in the next 12 months, approximately when will that be?: _____(month)_____(year)

Please skip to question 3 below.

- 1.b. Approximately, when did your business unit first acquire an Ada compiler?:

_____(month)_____(year)

- 1.c. Was the first Ada compiler acquired in order to execute a specific software development project?
(i.e., in contrast to a general, not project specific, need)

Yes: _____ No: _____ Don't Know: _____

- 1.d. At the time of its acquisition, was the first Ada compiler sufficiently mature such that it could be used without customization (e.g. changes in run-time software) in your production environment?:

Yes: _____ No: _____ Don't Know: _____

- 1.e. At the time of its acquisition, was the first Ada compiler validated?:

Yes: _____ No: _____ Don't Know: _____

2. Approximately, how many different Ada compilers* are either currently in use, or have been used by your business unit in a production environment?: _____ (* - Vendor/ target/ host combinations; do not include multiple versions of the same compiler)

3. Approximately, how many different Ada compilers* has your business unit evaluated for use in a production environment?: _____ (* - Vendor/ target/ host combinations; do not include multiple versions of the same compiler)

Section D. Ada Compilers/Tools: (cont'd)

D.5. Firm/Business Unit Relationship with Vendors: If your business unit has not committed funds to acquire either Ada compilers or tools, please skip to the next page. If your business unit has committed funds to acquire either Ada compilers or tools, please answer the following questions.

1. For the Ada compilers/tools that your business unit purchases from vendors, do you feel that you get adequate support from the vendor after the sale? Yes: ☐ No: ☐ Don't Know: ☐

2. Briefly, what if any type of vendor support has your business unit requested or needed?:

3. From what vendors has your firm's (APPLICATION AREA) business unit purchased Ada compilers/tools?

4. Has your business unit or corporation established a formal long-term relationship with any Ada tool vendors?
Yes: ☐ No: ☐

If No: Please skip to the top of the next page.

If Yes: Please answer questions 4.a. through 4.c.

4.a. With how many vendors has your business unit established long-term relations?: _____

4.b. The nature of the relationship(s) is: (choose those that apply)

- ☐ Business unit or corporation has a long term contract with an Ada vendor.
- ☐ Business unit or corporation has purchased a significant amount of stock in an Ada tool vendor.
- ☐ Business unit or corporation has acquired an Ada tool vendor.
- ☐ Other (please describe briefly): _____

4.c. When was the first long-term relationship established?: _____(month)_____(year)

Section E. Ada Use In Your Firm's (APPLICATION AREA) Business Unit:

E.1. Pre-procurement Use:

1. Has your business unit used an Ada Program Design Language (PDL)? Yes: ___ No: ___

If No: Please answer 1.a.

If Yes: Please answer 1.b and 1.c.

1.a. Briefly, why has your business unit chosen not to use an Ada PDL?

Please skip to question 2

1.b. Approximately, when did your business unit first use an Ada PDL?: ___(month)___(year)

1.c. Approximately, on what percentage of software development efforts in your business unit do you currently use an Ada PDL?: ___%

2. Has your business unit built any Ada software systems as part of either government or self-sponsored R&D?

Yes: ___ No: ___

If No: Please skip to the next page.

If Yes: Please answer questions 2.a. through 2.d.

2.a. Approximately, when did your business unit begin its first Ada R&D project?: ___(month)___(year)

2.b. Was the first Ada R&D project funded by one of your customers? Yes: ___ No: ___

2.c. To date, how many Ada R&D projects has your business unit undertaken?: ___

2.d. The largest single Ada R&D project was approximately: ___ lines of executable code.

E.2. Proposed Use of Ada:

1. Has your business unit proposed to use Ada as the primary implementation language for the full-scale development of a (APPLICATION AREA) system? Yes: ___ No: ___

If No: Please skip to question 2

If Yes: Please answer question 1.a.

1.a. When did your business unit first propose to use Ada as the primary implementation language on a (APPLICATION AREA) development contract?: ___(month)___(year)

2. Currently, approximately what percentage of new development contracts does your firm's (APPLICATION AREA) business unit propose to implement primarily in:

___% Assembly languages

___% Ada

Other High-order languages (please specify language if more than ten percent)

___%

___%

___%

___%

___%
= 100 %

Total

Section E. Ada Use In Your Firm's (APPLICATION AREA) Business Unit: (cont'd)

E.3. Ada Use on Contracts:

1. Has your business unit been contracted to develop a (APPLICATION AREA) system for which Ada was the primary implementation language?: Yes: _____ No: _____

If No: Please skip to question 2

If Yes: Please answer question 1.a.

1.a. Approximately when did your business unit begin to develop a (APPLICATION AREA) system in Ada?:
 _____(month)_____(year)

2. Currently, approximately what percentage of new development contracts does your firm's (APPLICATION AREA) business unit implement primarily in:

_____ % Assembly languages

_____ % Ada

Other high-order languages (please specify language if more than ten percent)

_____ % _____

_____ % _____

_____ % _____

_____ % _____

_____ % Total

≡ 100 %

E.4. Ada Use: Language Features If your firm's (APPLICATION AREA) business unit has neither designed nor developed a software system in Ads, please skip to the next page.

To answer the following questions, please respond with a number between 1 and 7 where 1 means "To no extent", 4 means "To a moderate extent", and 7 means "To a great extent". If you do not know how a question should be answered, please choose "D/K". If a question is not applicable, choose "N/A".

1. To what extent does your business unit use each of the following features of Ada in the design and development of (APPLICATION AREA) systems?: (choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

	To no extent			To a moderate extent			To a great extent		
(a) Generics:	1	2	3	4	5	6	7	D/K	N/A
(b) Packages:	1	2	3	4	5	6	7	D/K	N/A
(c) Private Types:	1	2	3	4	5	6	7	D/K	N/A
(d) Derived Types:	1	2	3	4	5	6	7	D/K	N/A
(e) Access Types:	1	2	3	4	5	6	7	D/K	N/A
(f) Exceptions:	1	2	3	4	5	6	7	D/K	N/A
(g) Record Types:	1	2	3	4	5	6	7	D/K	N/A

Section F. Effects of Ada Use:

F.1. Expected Effects of Ada Use During Production:

1. Currently, for each of the software development stages below, what do you expect will be the effect of using Ada on the cost and time to develop new (APPLICATION AREA) software systems? Compared to development in the language(s) you might otherwise use,:

- | | |
|--|-------------------------------------|
| L- Ada use will take less time | L- Ada use will lower cost |
| S- Ada use will take about the same time | S- Ada use will cost about the same |
| M- Ada use will take more time | M- Ada use will increase cost |
| D/K- Don't know | D/K- Don't know |

	<u>Time</u>	<u>Cost</u>
(a) Requirements Analysis		
Top Level Design:.....	_____	_____
(b) Detailed Design:.....	_____	_____
(c) Code Unit Test:.....	_____	_____
(d) Integration and Test:.....	_____	_____
(e) Delivery and Initial FSD Support:.....	_____	_____
(f) Production Support:.....	_____	_____

2. Currently, what do you expect will be the effect of using Ada on the overall time to develop new (APPLICATION AREA) software systems? Compared to the language(s) your business unit might otherwise use, using Ada will most likely : (choose one)

- ☐ Increase overall software development time by _____ %
☐ Have no effect on overall software development time
☐ Decrease overall software development time by _____ %
☐ Don't Know

3. Currently, what do you expect will be the effect of using Ada on the overall cost to develop new (APPLICATION AREA) software systems? Compared to the language(s) your business unit might otherwise use, using Ada will most likely : (choose one)

- ☐ Increase overall software development cost by _____ %
☐ Have no effect on overall software development costs
☐ Decrease overall software development cost by _____ %
☐ Don't Know

4. How certain are you of the changes in overall software development costs that currently can be expected to come from the use of Ada to develop new (APPLICATION AREA) software systems?: (choose an integer between 1 and 7, or "D/K" for Don't Know)

Not at all									
Certain.....			Moderately				Extremely		
			Certain.....				Certain		
1	2	3	4	5	6	7	D/K		

Section F. Effects of Ada Use:

F.1. Expected Effects of Ada Use During Production:(cont'd)

5. Three years from now, what do you expect will be the effect of using Ada on the overall cost to develop new (APPLICATION AREA) software systems? Compared to the language(s) your business unit might otherwise use, using Ada will most likely: (choose one)

- ☐: Increase overall software development costs by _____ %
- ☐: Have no effect on overall software development costs
- ☐: Decrease overall software development costs by _____ %
- ☐: Don't Know

6. How certain are you of your expectations of changes in overall software development costs that would come from the use of Ada to develop new (APPLICATION AREA) software systems three years from now?: (choose an integer between 1 and 7, or "D/K" for Don't Know)

- | | | | | | | | | |
|--------------|---|---|---|------------|---|---|-----|-----------|
| Not at all | | | | | | | | Extremely |
| Certain..... | | | | Moderately | | | | Certain |
| | | | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | D/K | |

F.2. Expected Effects of Ada Use After Development:

1. Compared to similar systems implemented in other languages, what do you expect to be the effect of the use of Ada on your software sustaining direct labor costs?: (choose one)

- ☐: Expectations are that Ada sustaining costs will be higher
- ☐: Expectations are that Ada sustaining costs will be about the same
- ☐: Expectations are that Ada sustaining costs will be lower
- ☐: Don't know

2. Compared to similar systems implemented in other languages, what do you expect to be the effect of the use of Ada on the number of Class I errors filed against the systems you develop?: (choose one)

- ☐: Expectations are that the number of errors using Ada will be higher
- ☐: Expectations are that the number of errors using Ada will be about the same
- ☐: Expectations are that the number of errors using Ada will be lower
- ☐: Don't know

3. Compared to similar systems implemented in other languages, what do you expect to be the effect of the use of Ada on the number of Class II errors filed against the systems you develop?: (choose one)

- ☐: Expectations are that the number of errors using Ada will be higher
- ☐: Expectations are that the number of errors using Ada will be about the same
- ☐: Expectations are that the number of errors using Ada will be lower
- ☐: Don't know

4. What do you expect the use of Ada for the development of a (APPLICATION AREA) system will have on post-development software support costs? Compared to the language(s) your business unit might otherwise use, using Ada for the development of (APPLICATION AREA) software will most likely: (choose one)

- ☐: Increase overall post-development software support costs by _____ %
- ☐: Have no effect on overall software development costs
- ☐: Decrease overall post-development software support costs by _____ %
- ☐: Don't Know

Section G. Factors Affecting the Adoption or Nonadoption of Ada in Your Firm's (APPLICATION AREA) Business Unit

1. For your firm's (APPLICATION AREA) business unit, to what extent has the decision of whether or not to adopt Ada been responsive to each of the following factors?: (for each factor below choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" if the question is not applicable)

	To no extent		To a moderate extent				To a great extent			
(a) Current customer demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(b) Expected future demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(c) Uncertainty about expected demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(d) Current software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(e) Expected future software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(f) Current costs of acquiring Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	
(g) Expectation that Ada adoption costs are declining with time:	1	2	3	4	5	6	7	D/K	N/A	
(h) Fear of being left behind competitors in developing Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	

If your firm's (APPLICATION AREA) business unit has made investments to develop Ada capabilities, please answer the following question.

2. To what extent has the level of investment in Ada personnel, tools, R&D, e.c. made by your firm's (APPLICATION AREA) business unit been responsive to each of the following factors?: (for each factor below choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" if the question is not applicable)

	To no extent		To a moderate extent				To a great extent			
(a) Current customer demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(b) Expected future demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(c) Uncertainty about expected demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(d) Current software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(e) Expected future software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(f) Current costs of acquiring Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	
(g) Expectation that Ada adoption costs are declining with time:	1	2	3	4	5	6	7	D/K	N/A	
(h) Fear of being left behind competitors in developing Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	

Thank you again for your participation in this research.

Business/Market Questionnaire

Section A. Firm Size: Questions in the first section of this questionnaire are intended to elicit measures of the size of your firm, the scope of your firm's activities, and the software development environment in that part of your firm (business unit) that makes (APPLICATION AREA) systems and software.

A.1. Business Unit Size:

1. Approximately, what were the revenues of your firm's (APPLICATION AREA) business unit last year?
\$ _____
2. Approximately, how many people are employed by that business unit? _____
3. How many (APPLICATION AREA) contracts are currently active in the business unit?: _____

A.2. Division Size: (If applicable)

1. Approximately, what were the revenues of the division last year?: \$ _____
2. Approximately, how many people are employed by the division?: _____
3. Approximately, how many different MCCR product markets (i.e., distinct applications or types of systems) does the division supply?: _____

A.3. Corporate/Company Size: (If applicable)

1. Approximately, what were the revenues of the company last year?: \$ _____
2. Approximately, how many people are employed by the company?: _____
3. Approximately, how many different MCCR product markets (i.e., distinct applications or types of systems) does the company supply?: _____

Section A. Firm Size: (cont'd)

A.4. Scope of Firm Activities In (APPLICATION AREA) Market:

Software/ Hardware Components:

1. In what year did your firm begin supplying software for (APPLICATION AREA) applications?: _____
2. In addition to software, what other components associated with (APPLICATION AREA) systems does your firm manufacture: (choose those that apply)

- ____: Firm does not manufacture other components; Please go to the questions on R&D below
- ____: Computer hardware on which the software runs
- ____: Peripheral equipment (e.g. sensors, displays)
- ____: Weapon system platform
- ____: Other (please specify)

- 2.a. To what extent do your firm's potential sales of non-software (APPLICATION AREA) components depend upon your firm's ability to supply the software component?: (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent	To a moderate extent				To a great extent		
1	2	3	4	5	6	7	D/K

- 2.b. To what extent do potential sales of non-software components influence the choice of (APPLICATION AREA) software contracts on which your business unit bids? (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent	To a moderate extent				To a great extent		
1	2	3	4	5	6	7	D/K

Research and Development (R&D):

1. Over the past three years, what has been the average annual expenditure for research and development (R&D) by your firm's (APPLICATION AREA) business unit? (Please include both company and government financed R&D):

\$ _____ / year Don't Know: _____

2. Approximately, what percentage of the business unit's R&D expenditures have been applied to the development of software technology? _____% Don't Know: _____

- 2.a. In turn, what percentage of these R&D expenditures on software have been targeted for developing Ada capabilities?: _____% Don't Know: _____

A.4. Scope of Firm Activities in (APPLICATION AREA) Market: (cont'd)
Research and Development (R&D):

3. Approximately, what percentage of the business unit's total R&D expenditures comes from each of the following sources? (the summation of percentages should be approximately 100%)

- ☐ % Contract awards for R&D
☐ % Company sponsored R&D funds (excluding IR&D)
☐ % IR&D funds
 Other sources (Please specify if more than 10%)
☐ % _____
☐ % _____
☐ % _____
☐ % _____
☐ % _____
 = 100 % Total

B. Software Development Organization: In this section we ask questions intended to get a general picture of the personnel and overall capabilities in the part of your firm that produces software for (APPLICATION AREA) systems.

1. Approximately, how many software personnel are currently employed by your firm's (APPLICATION AREA) business unit? _____ (do not include temporary personnel that may be contracted to cover peak staffing on projects)

2. Approximately, how many software personnel were employed by your firm's (APPLICATION AREA) business unit three years ago? _____ Don't Know: _____ Not Applicable: _____

3. What is the average tenure (years employed by your company) of the software development staff in your business unit? (choose one)

- ☐ : 0 - < 2 years
☐ : 2 - < 4 years
☐ : 4 - < 6 years
☐ : 6 - < 8 years
☐ : 8 - < 10 years
☐ : 10 years or more

3.a. How does your business unit's turnover rate of software personnel compare to the firms with which you compete for (APPLICATION AREA) development contracts? Is the turnover rate in your firm's (APPLICATION AREA) business unit: (choose an integer from 1 to 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

Significantly Lower than Average				About Average			Significantly Higher than Average		
1	2	3	4	5	6	7	D/K	N/A	

4. Compared to the firms with which you compete for (APPLICATION AREA) software development contracts, how would you rate your business unit's software development capabilities? Are your business unit's software development capabilities: (choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

Significantly Worse than Average				About Average			Significantly Better than Average		
1	2	3	4	5	6	7	D/K	N/A	

Section C. Competitors and the Market for (APPLICATION AREA) Systems:

C.1. Competing Firms:

1. Currently, how many contractors can creditably compete for contracts to develop (APPLICATION AREA) systems?
_____ (please include your own firm in the count)

2. How does the number of competing contractors today compare to the number of contractors three years ago? Was the number of competing contractors three years ago: (choose one)

- ____ : Higher than today
- ____ : About the same as today
- ____ : Lower than today
- ____ : Don't know

2.b. If the number of competing contractors three years ago was either higher or lower:
Approximately, how many contractors were competing for contracts to develop (APPLICATION AREA) systems three years ago?: _____

3. In three years the number of contractors competing to develop (APPLICATION AREA) systems will most likely be: (choose one)

- ____ : Higher than today
- ____ : About the same as today
- ____ : Lower than today
- ____ : Don't know

3.b. If you think the number of competing contractors in three years will likely be either higher or lower:
Approximately, how many contractors will most likely be competing for contracts to develop (APPLICATION AREA) systems three years from now?: _____

4. Currently, what firms do you directly compete with for (APPLICATION AREA) contracts?:

Company Name and Division Name (if applicable):

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

C.2. Market Shares:

1. The firm with the largest market share supplies approximately what percentage of the (APPLICATION AREA) market?:
_____ %

2. The firm with the second largest market share?: _____ %

3. Combined, the four firms with the largest market shares supply approximately what percentage of the (APPLICATION AREA) market?: _____ %

4. Approximately, what percentage of the (APPLICATION AREA) market does your company supply?: _____ %

Section D. (APPLICATION AREA) Market Size and Activity:

1. Since 1985, the average dollar value of a single (APPLICATION AREA) development contract has been approximately: \$ _____

2. Since 1985, annual customer expenditures for the development of (APPLICATION AREA) systems have been approximately: \$ _____ / year

2.b. In terms of the dollar value of contracts awarded, the market for (APPLICATION AREA) systems since 1985 has: (choose one)

- ☐ : Decreased approximately _____ %
☐ : Stayed about the same
☐ : Increased approximately _____ %

2.c. What are your expectations of customer expenditures for (APPLICATION AREA) systems over the next three years? Expenditures will: (choose one)

- ☐ : Decrease approximately _____ %
☐ : Stay about the same
☐ : Increase approximately _____ %

3. Approximately, how many contracts for the development of new (APPLICATION AREA) software have been let over the past three years?: _____

4. On average, how frequently are new (APPLICATION AREA) programs started?: _____ (Approximate time between RFPs for the development of new systems expressed in either months or years)

5. A delivered (APPLICATION AREA) system may be expected to be in the customer's operational inventory for approximately _____ years. (Time from first system deployed to last system taken out of operational duty)

6. Currently, what percentage of project cost on a (APPLICATION AREA) development contract can be attributed to the development of software?: _____ %

6.b. Three years ago the percentage of project cost on a (APPLICATION AREA) development contract that could be attributed to the development of software was approximately : _____ %.

6.c. Three years from now the percentage of project cost on a (APPLICATION AREA) development contract that may be attributed to the development of software will approximately be: _____ %.

7. Over the lifetime of a typical (APPLICATION AREA) system, DoD expenditures for system software may be divided approximately as follows:

- _____ %: Initial Development/Production of Software up to its Acceptance/Deployment
_____ %: Modifications, Enhancements, and Maintenance of the Software after Initial Acceptance/Deployment

Section E. Contracting Conditions and Customer:

E.1. Contracting Conditions:

1. Over the past three years, the most common contract terms for the development of new (APPLICATION AREA) software systems has been: (choose one)

- ☐ : Firm Fixed-Price
- ☐ : Cost Plus Award Fee
- ☐ : Fixed Price Incentive
- ☐ : Cost Plus Incentive Fee
- ☐ : Cost Plus-Fixed-Fee
- ☐ : Other (please specify) _____

2. When your company supplies (APPLICATION AREA) software, what percentage of the time does it act as: (the summation of percentages should be approximately equal to 100)

- _____ % Prime contractor
- _____ % Subcontractor
- _____ % Team member
- _____ % Other arrangements (please specify) _____

_____ \approx 100 %

2.a. If your firm acts as a subcontractor more than 20% of the time, what companies are likely to be the prime contractor?

Company Name and Division Name (if applicable):

E.2. Customer:

1. Over last three years, approximately what percentage of the (APPLICATION AREA) systems that your company has built has been for use by the following:

- _____ % U.S. Air Force
- _____ % U.S. Army
- _____ % U.S. Navy
- _____ % Other DoD agencies
- _____ % Other Federal agencies or departments (i.e., excluding DoD)

2. Based on your experiences and the descriptions below, how would you characterize your primary customer's understanding of the software development process? (choose an integer from 1 to 7, or "D/K" for Don't Know)

- 1 No understanding; software is essentially a "black box" to the customer,
- 4 Moderate understanding; the customer has some appreciation of the software development, but may not fully understand the difficulties of developing software in the application area
- 7 Complete understanding; the customer is extremely knowledgeable about the development of software and the trade-offs that are made during design and development

1 2 3 4 5 6 7 D/K

Section E. Contracting Conditions and Customer
E.2. Customer: (cont'd)

3. Using the scale below, indicate to what extent you believe the following factors influence your primary customer's choice of firm when awarding contracts for the development of new (APPLICATION AREA) software or systems?:
(for each factor below, choose an integer from 1 to 7, or "D/K" for Don't Know)

	To no extent		To a moderate extent				To a great extent		
(a) Contractor experience in the application domain:	1	2	3	4	5	6	7	D/K	
(b) Overall project cost:	1	2	3	4	5	6	7	D/K	
(c) Timeliness of projected project delivery:	1	2	3	4	5	6	7	D/K	
(d) Proposed product performance:	1	2	3	4	5	6	7	D/K	
(e) Contractor software capabilities:	1	2	3	4	5	6	7	D/K	
(f) Projected software development cost:	1	2	3	4	5	6	7	D/K	
(g) Expected costs of software maintenance:	1	2	3	4	5	6	7	D/K	
(h) Ease of software maintenance:	1	2	3	4	5	6	7	D/K	
(i) Software portability:	1	2	3	4	5	6	7	D/K	
(j) Briefly, what other factors seem to be important to your primary customer in awarding (APPLICATION AREA) development project contracts?									

4. To what extent does the contractor who developed the last (APPLICATION AREA) system have an extra advantage in getting the next (APPLICATION AREA) development contract?: (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent.....	To a moderate extent.....				To a great extent.....		
1	2	3	4	5	6	7	D/K

5. To what extent do you believe your primary customer for (APPLICATION AREA) systems would be willing to trade lower costs in the long-run for greater costs during project procurement/development?: (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent.....	To a moderate extent.....				To a great extent.....		
1	2	3	4	5	6	7	D/K

6. To what extent do you believe your primary customer for (APPLICATION AREA) systems would be willing to trade lower costs in the long-run for greater short-term schedule and cost risks during project procurement/development?: (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent.....	To a moderate extent.....				To a great extent.....		
1	2	3	4	5	6	7	D/K

Section F. Demand Conditions in the (APPLICATION AREA) Market:

1. Suppose that your firm could reduce the costs of developing the software for (APPLICATION AREA) systems by 25%. Holding all other factors constant, what would be the effect on the revenues that your firm could expect from a single (APPLICATION AREA) development contract? (choose one)

- ☐: Revenues would decrease approximately _____%
- ☐: Revenues would be approximately the same
- ☐: Revenues would increase approximately _____%

2. Suppose that your firm could reduce the price that your customer pays for software development services by 25%. Allowing only for a change in demand (either more systems or more elaborate systems) what do you expect would be the net change to revenues that your business unit could expect from (APPLICATION AREA) development contracts: (choose one)

- ☐: Revenues would decrease approximately _____%
- ☐: Revenues would be approximately the same
- ☐: Revenues would increase approximately _____%

3. Suppose that your firm could lower the costs of maintaining (APPLICATION AREA) software by 25%. Holding software production costs constant, what do you believe would happen to the demand (either more systems or more elaborate systems) for new software in your application area?: (choose one)

- ☐: Demand would decrease approximately _____%
- ☐: Demand would be approximately the same
- ☐: Demand would increase approximately _____%

4. Suppose it cost your firm one hundred thousand dollars less to develop software for a (APPLICATION AREA) system. How much of that the \$100,000 could your firm keep, and how much of it would be passed along to your customer through a lower price?: (summation of values should be approximately \$100,000)

- \$ _____ : Firm Keeps
- \$ _____ : Customer Gets

Section G. Ada In the (APPLICATION AREA) Market:

1. Approximately, when was the first contract awarded to a firm that proposed to use Ada as the primary implementation language for the development of a (APPLICATION AREA) system?:

_____(month) _____(year)

_____: Has not happened

2. During the calendar years 1986-1989, the percentage of new (APPLICATION AREA) development contracts that have been awarded to contractors proposing to use Ada as the primary implementation language was: _____%

3. What are your expectations of the percentage of new development contracts in the application area for which Ada will be the required language in each of the three calendar years:

_____% 1989

_____% 1990

_____% 1991

4. How certain are you of your primary customer's demand for Ada software in this application area over the next three years?: (choose an integer from 1 to 7, or "D/K" for Don't Know)

Not at all Certain.....				Moderately Certain.....				Extremely Certain.....	
1	2	3	4	5	6	7	D/K		

5. What is your perception of your primary customer's *present* attitude toward the use of Ada for the development of software for (APPLICATION AREA) systems?: (choose an integer from 1 to 7, or "D/K" for Don't Know)

- 1 The customer is extremely adverse to the use of Ada for the development of systems in this application area; very unlikely to buy a system written in Ada;
- 2 The customer prefers to use another language for the development of systems in this application area but would consider using Ada if there were strong evidence that use of Ada would have significant product/project benefits;
- 4 The customer is indifferent to the language used for the development of systems in this application area; choice of language is strictly based on the effect of the languages' abilities to meet implicit and explicit product/project specifications;
- 5 The customer prefers the use of Ada, but would consider using other languages for the development of parts of systems if there is strong evidence that their use would have significant product/project benefits;
- 7 The customer insists on the use of Ada for all software in this application area.

1	2	3	4	5	6	7	D/K
---	---	---	---	---	---	---	-----

6. Based on the descriptions above, what was your primary customer's attitude toward the use of Ada for the development of software for (APPLICATION AREA) systems? (choose an integer from 1 to 7, or "D/K" for Don't Know)

One year ago?: _____

Three years ago?: _____

If applicable, at the time of your business unit's first use of Ada?: _____

Three years from now?: _____

Section H. Ada Use In Your Firm's (APPLICATION AREA) Business Unit:

H.1. Ada Compiler(s): Acquisition

1. Has your firm's (APPLICATION AREA) business unit acquired (e.g. purchase, lease, rent, time share, or develop) an Ada compiler?:

Yes: _____ No: _____

If No: Please answer question 1.a.

If Yes: Please answer questions 1.b. through 1.d.

1.a. Do you anticipate that the business unit will acquire an Ada compiler within the next 12 months?

Yes: _____ No: _____ Don't Know: _____

If you expect the business unit will acquire an Ada compiler in the next 12 months, approximately when will that be?: _____ (month) _____ (year)

Please skip to question 2 below.

1.b. Approximately, when did the business unit first acquire an Ada compiler?:

_____ (month) _____ (year)

1.c. Was the first Ada compiler acquired in order to execute a specific software development project? (i.e., in contrast to a general, not project specific, need)

Yes: _____ No: _____ Don't Know: _____

1.d. At the time of its acquisition, was the first Ada compiler validated?:

Yes: _____ No: _____ Don't Know: _____

2. Approximately, how many different Ada compilers* are either currently in use, or have been used by your firm's (APPLICATION AREA) business unit in a production environment?: _____ (* - Vendor/ target/ host combinations, do not include multiple versions of the same compiler)

3. Approximately, how many different Ada compilers* has your firm's (APPLICATION AREA) business unit evaluated for use in a production environment?: _____ (* - Vendor/ target/ host combinations; do not include multiple versions of the same compiler)

H.2. Ada Compilers and Tools: Costs

Current Acquisition Costs

1. Approximately, what can a firm that builds (APPLICATION AREA) software expect to spend (purchase price, plus the cost of customization if needed) to acquire a production quality Ada compiler, linker, and loader?:

\$ _____ Don't Know: _____

2. In addition to the costs of the minimal set of tools (compiler, linker and loader), how much can a firm that builds (APPLICATION AREA) software expect to spend on other Ada specific software development tools and additional computing facilities?: \$ _____ Don't Know: _____

Acquisition Costs Over Time

3. Compared to Ada software tools that are currently available: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Less Expensive		Approximately the Same			Significantly More Expensive		
(a) Three years ago, Ada software tools were:	1	2	3	4	5	6	7	D/K
(b) Three years from now, Ada software tools will most likely be:	1	2	3	4	5	6	7	D/K

Section H. Ada Use In Your Firm's (APPLICATION AREA) Business Unit: (cont'd)

H.3. Ada and Personnel: In Your Firm's (APPLICATION AREA) Business Unit

1. Has your business unit developed (e.g. new hires or training programs) Ada capabilities in your software development staff?: Yes: _____ No: _____ Don't Know: _____

If No or Don't Know: Please skip to question 2

If Yes: Please answer questions 1.a. through 1.e.

1.a. Approximately, when did you begin to develop Ada capabilities in your business unit's software development staff?:

_____ (month) _____ (year)

1.b. Of the Ada trained software personnel in your business unit, what percentage received their primary Ada training in courses sponsored or paid for by your firm: _____%

1.c. Currently, what percentage of all software personnel in your business unit have enough training in Ada such that they could be used to generate code on an Ada software development program?: _____%

1.d. Currently, what percentage of all software designers in your business unit have enough training in Ada such that they could develop designs for an Ada software development program?: _____%

1.e. Currently, what percentage of your software staff have experience developing Ada software systems in the (APPLICATION AREA) domain?: _____%

2. Approximately, what do you expect is the per capita cost to train your software personnel to design and implement (APPLICATION AREA) software systems in Ada?: \$ _____/person Don't Know: _____

H.4 Ada and Personnel: External Labor Markets

1. Compared to software personnel with otherwise similar abilities and experience, how much more difficult is it to hire programming staff and software/system designers with Ada capabilities? (choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" for Not Applicable)

	No More Difficult		Moderately More Difficult			Significantly More Difficult		More Difficult	
(a) Programming Staff:	1	2	3	4	5	6	7	D/K	N/A
(b) Software/System Designers:	1	2	3	4	5	6	7	D/K	N/A

2. How much of a salary premium is commanded by programming staff and software/system designers with Ada capabilities?: (please estimate to nearest 5%)

(a) On average, programming staff with Ada capabilities may expect _____% of the salary of programming staff with otherwise similar abilities and experience.

(b) On average, software/system designers with Ada capabilities may expect _____% of the salary of software/system designers with otherwise similar abilities and experience.

3. Compared to current costs of hiring/training Ada personnel: (choose an integer between 1 and 7, or "D/K" for Don't Know)

	Significantly Less Expensive		Approximately the Same			Significantly More Expensive		
(a) Three years ago, Ada personnel costs were:	1	2	3	4	5	6	7	D/K
(b) Three years from now, Ada personnel costs will most likely be:	1	2	3	4	5	6	7	D/K

Section H. Ada Use in Your Firm's (APPLICATION AREA) Business Unit: (cont'd)

H.5. Ada Use: Proposed/ Implemented

Proposed Use of Ada:

1. Has your business unit proposed to use Ada as the primary implementation language for the full-scale development of a (APPLICATION AREA) system? Yes: ____ No: ____

If No: Please skip to question 2

If Yes: Please answer question 1.a.

1.a. When did your business unit first propose to use Ada as the primary implementation language on a (APPLICATION AREA) development contract? ____ (month) ____ (year)

2. Currently, approximately what percentage of new development contracts does your firm's (APPLICATION AREA) business unit propose to implement primarily in:

____ % Assembly languages
____ % Ada
____ % Other high-order languages (please specify language if more than ten percent)
____ % _____
____ % _____
____ % _____
____ % _____

____ %
= 100 % Total

Ada Use on Contracts:

1. Has your business unit been contracted to develop a (APPLICATION AREA) system for which Ada was the primary implementation language? Yes: ____ No: ____

If No: Please skip to question 2

If Yes: Please answer question 1.a.

1.a. Approximately when did your business unit begin to develop a (APPLICATION AREA) system in Ada? ____ (month) ____ (year)

2. Currently, approximately what percentage of new development contracts does your firm's (APPLICATION AREA) business unit implement primarily in:

____ % Assembly languages
____ % Ada
____ % Other high-order languages (please specify language if more than ten percent)
____ % _____
____ % _____
____ % _____
____ % _____

____ %
= 100 % Total

Section I. Effects of Ada Use:

I.1. Expected Effects of Ada Use During Production:

1. Currently, for each of the software development stages below, what do you expect will be the effect of using Ada on the cost and time to develop new (APPLICATION AREA) software systems? Compared to development in the language(s) you might otherwise use.:

- L- Ada use will take less time
- S- Ada use will take about the same time
- M- Ada use will take more time
- D/K- Don't know

- L- Ada use will lower cost
- S- Ada use will cost about the same
- M- Ada use will increase cost
- D/K- Don't know

	<u>Time</u>	<u>Cost</u>
(a) Requirements Analysis		
Top Level Design:.....	_____	_____
(b) Detailed Design:.....	_____	_____
(c) Code Unit Test:.....	_____	_____
(d) Integration and Test:.....	_____	_____
(e) Delivery and Initial FSD Support:.....	_____	_____
(f) Production Support:.....	_____	_____

2. Currently, what do you expect will be the effect of using Ada on the overall time to develop new (APPLICATION AREA) software systems? Compared to the language(s) your business unit might otherwise use, using Ada will most likely : (choose one)

- ___: Increase overall software development time by _____%
- ___: Have no effect on overall software development time
- ___: Decrease overall software development time by _____%
- ___: Don't Know

3. Currently, what do you expect will be the effect of using Ada on the overall cost to develop new (APPLICATION AREA) software systems? Compared to the language(s) your business unit might otherwise use, using Ada will most likely : (choose one)

- ___: Increase overall software development cost by _____%
- ___: Have no effect on overall software development costs
- ___: Decrease overall software development cost by _____%
- ___: Don't Know

4. How certain are you of the changes in overall software development costs that currently can be expected to come from the use of Ada in your application area?: (choose an integer between 1 and 7, or "D/K" for Don't Know)

Not at all									
Certain.....			Moderately					Extremely	
			Certain.....					Certain	
1	2	3	4	5	6	7	D/K		

1.1. Expected Effects of Ada Use During Production:(cont'd)

☐ : Increase overall software development cost by _____%
☐ : Have no effect on overall software development costs
☐ : Decrease overall software development cost by _____%
☐ : Don't Know

Not at all Certain.....			Moderately Certain.....		Extremely Certain.....		
1	2	3	4	5	6	7	D/K

☐ Expectations are that Ada sustaining costs will be higher
☐ Expectations are that Ada sustaining costs will be about the same
☐ Expectations are that Ada sustaining costs will be lower
☐ Don't know

- ☐ Expectations are that the number of errors using Ada will be higher
- ☐ Expectations are that the number of errors using Ada will be about the same
- ☐ Expectations are that the number of errors using Ada will be lower
- ☐ Don't know

- ___: Expectations are that the number of errors using Ada will be higher
- ___: Expectations are that the number of errors using Ada will be about the same
- ___: Expectations are that the number of errors using Ada will be lower
- ___: Don't know

☐ : Increase overall post-development software support costs by _____%
☐ : Have no effect on overall software development costs
☐ : Decrease overall post-development software support costs by _____%
☐ : Don't Know

Section J. Factors Affecting the Adoption or Nonadoption of Ada In Your Firm's (APPLICATION AREA) Business Unit

1. For your firm's (APPLICATION AREA) business unit, to what extent has the decision of whether or not to adopt Ada been responsive to each of the following factors?: (for each factor below choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" if the question is not applicable)

	To no extent		To a moderate extent				To a great extent			
(a) Current customer demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(b) Expected future demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(c) Uncertainty about expected demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(d) Current software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(e) Expected future software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(f) Current costs of acquiring Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	
(g) Expectation that Ada adoption costs are declining with time:	1	2	3	4	5	6	7	D/K	N/A	
(h) Fear of being left behind competitors in developing Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	

If your firm's (APPLICATION AREA) business unit has not made investments to develop Ada capabilities, please skip to the next page.

If your firm's (APPLICATION AREA) business unit has made investments to develop Ada capabilities, please answer the following question.

2. To what extent has the level of investment in Ada personnel, tools, R&D, etc. made by your firm's (APPLICATION AREA) business unit been responsive to each of the following factors?: (for each factor below choose an integer between 1 and 7, "D/K" for Don't Know, or "N/A" if the question is not applicable)

	To no extent		To a moderate extent				To a great extent			
(a) Current customer demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(b) Expected future demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(c) Uncertainty about expected demand for Ada:	1	2	3	4	5	6	7	D/K	N/A	
(d) Current software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(e) Expected future software development costs using Ada:	1	2	3	4	5	6	7	D/K	N/A	
(f) Current costs of acquiring Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	
(g) Expectation that Ada adoption costs are declining with time:	1	2	3	4	5	6	7	D/K	N/A	
(h) Fear of being left behind competitors in developing Ada capabilities:	1	2	3	4	5	6	7	D/K	N/A	

Section J. Factors Affecting the Adoption or Nonadoption of Ada in Your Firm's
(APPLICATION AREA) Business Unit (cont'd)

3. To what extent do you believe firms in the (APPLICATION AREA) market that currently have Ada capabilities have or will have an extra advantage in getting new development contracts? (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent.....				To a moderate extent.....			To a great extent.....	
1	2	3	4	5	6	7	D/K	

4. To what extent do you believe firms in the (APPLICATION AREA) market that develop Ada capabilities later than their competitors are or will be at an extra disadvantage in getting new development contracts? (choose an integer from 1 to 7, or "D/K" for Don't Know)

To no extent.....				To a moderate extent.....			To a great extent.....	
1	2	3	4	5	6	7	D/K	

Thank you again for your participation in this research.